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RESEARCH ARTICLE

HUMAN HAIR AS FIBRE REINFORCEMENT IN CONCRETE: AN ALTERNATIVE METHOD OF HAIR WASTE MANAGEMENT AND ITS APPLICATIONS IN CIVIL CONSTRUCTIONS

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ABSTRACT

Human hair is considered as a waste material in most parts of the world and is a common constituent found in municipal waste streams which cause enormous environmental problems. This is an attempt to find the possibilities of using hair as fibre reinforcement in concrete, thereby forming an alternative way for the safe management of hair waste. Human hair is strong in tension; hence it can be used as a fibre reinforcement material. Hair Fibre, an alternate non-degradable matter, is available in abundance and at a very cheap cost. Present studies have been undertaken to analyse the effect of human hair on plain cement concrete on the basis of compressive, crushing and flexural strengths and cracking control to economize concrete and to reduce environmental problems. Experiments were conducted on concrete cubes with various percentages of human hair fibre i.e. 0%, 1.5% and 2% by weight of cement. By testing we found that there is an increment in the various properties and strength of concrete by the addition of human hair as fibre reinforcement which makes it suitable for an alternative additive for concrete to enhance its mechanical properties. Also, hair fibre reinforced concrete can be an alternative method for the hair waste management.

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INTRODUCTION

Background for the Study

There had been news in a local news paper describing the problems caused by human hair waste from saloons and beauty parlours in and around Thrissur district in Kerala. Earlier times, the hair waste has been collected and exported to a company in Tamil Nadu for making amino acids from hair fibre. But later on the company ended its functioning which created problems in disposal and removal of hair waste in the district. We conducted a rough survey among the workers of beauty parlours and saloons about the disposal of hair waste and majority of them agreed that there is no effective method for the disposal of non bio degradable hair so that they have been discarding it as such. It was in this context we searched for an alternative way of disposing hair and arrived at the possibility of adding hair fibre as reinforcement in concrete. Tests have been conducted to find the suitability of hair as fibre reinforcement in concrete and arrived at conclusions

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Human Hair

The hair thread has a cylindrical structure, highly organized, formed by inert cells, most of them keratinized and distributed following a very precise and pre-defined design. Hair forms a very rigid structure in the molecular level, which is able to offer the thread both flexibility and mechanical resistance. Human hair has about 65-95% of its weight in proteins, more 32% of water, lipid pigments and other components. Chemically, about 80% of human hair is formed by a protein known as keratin (Kaplin *et al.,* 1982; Wagner, Joekes, 2005), with a high grade of sulphur. The primary component of hair fibre is keratin. Keratins are proteins, long chains (polymers) of amino acids. In terms of raw elements, on average, hair is composed of 50.65% carbon, 20.85% oxygen, 17.14% nitrogen, 6.36% hydrogen, and 5.0% sulphur. Keratin gives the hair strength, flexibility, durability, and functionality.

Human Hair as Fibre Reinforcement in Concrete

Fibre-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented.

The principle of the fibre concrete or fibre cement has been around since ancient world. Romans and Egyptians put straw or hair into the building material and improved the mechanical properties through these additions. Hair is surprisingly strong. Cortex keratin is responsible for this propriety and its long chains are compressed to form a regular structure which, besides being strong, is flexible (Dias, 2004; Robbins, 1994). The physical proprieties of hair involve: resistance to stretching, elasticity and hydrophilic power. The resistance to breakage is a function of the diameter of the thread, of the cortex condition. Hair fibre has an elastic characteristic, and it may undergo moderate stretching either wet or dry. When dry, the hair thread may stretch 20-30% of its length; and, in contact with water, this may reach up to 50%.

MATERIALS AND METHODS

Preparation of Specimen

The hair needed for the preparation of concrete cubes was collected from salons and beauty parlours. It needs treatment before to be added in the concrete specimens. The treatment was done through different stages in which hair was separated from other wastes followed by washing it with acetone, drying and sorting.

Compressive Strength Test on Cubes

The test is carried out in the following steps: First of all the mould preferably of cast iron, is used to prepare the specimen of size 150 × 150 × 150 mm. Calculated quantity of hair fibre is evenly added into the concrete mix manually.

The specimen for the test is made in the following manner: Three cubes are made for each M15, M2O and M25 with 0%, 1.5% and 2% hair by weight of cement. The results from the compression test are in the form of the maximum load the cube can carry before it ultimately fails. The compressive strength can be found by dividing the maximum load by the contact area (150x150mm^2) of the test specimen.

RESULTS

When M15 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 8.5% in compressive strength and when M15 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 12% in compressive strength. When M20 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 1% in compressive strength and when M20 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 6.3% in compressive strength. When M25 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 1% in compressive strength and when M25 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 4.44% in compressive strength.

Flexural Strength Test

The system of loading used in finding out the flexural tension is Third-point Loading Method. In this method the critical crack may appear at any section, where the bending moment is maximum.

Table 1. Compressive strength test results of cubes

Sl No.	Mix Design	Average compressive force(kN)	Avg. Compressive strength(N/mm^2)
1	M15 : without hair	382.5	16.89
	1.5% hair	412.5	18.33
	2% hair	425	18.88
2	M20 : without hair	463.3	20.587
	1.5% hair	467.5	20.77
	2% hair	492.5	21.885
3	M25 : without hair	562.5	24.995
	1.5% hair	570	25.215
	2% hair	587.5	26.105

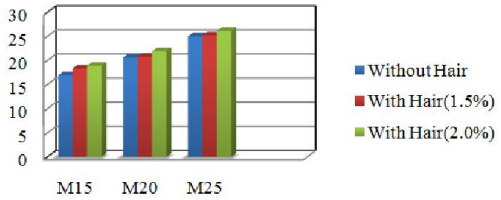

Fig. 1. Comparison on the basis of average compressive strength with varying percentages of hair fibre

During the placing of concrete in the moulds it is compacted with the tamping bar with not less than 25 strokes per layer. After 24 hours the specimens are removed from the moulds and immediately submerged in clean fresh water. After 28 days the specimens are tested under the load in a compression testing machine. The load is applied uniformly at the rate of 14 N/mm^2 in the compression testing machine.

The test is carried out in the following steps: First of all the mould preferably of cast iron, is used to prepare the specimen of size 150 × 150 × 700 mm. During the placing of concrete in the mould it is compacted with the tamping bar with not less than 25 strokes per layer. After 24 hours the specimens are removed from the moulds and immediately submerged in clean fresh water.

Table 2. Flexural strength of cubes

Sl. No.	Mix ratio	Average Compressive strength of cube(N/mm^2)	Average flexural strength of cube(N/mm^2)
1	M15: without hair	16.89	2.877
2	1.5% hair	18.33	2.997
3	2% hair	18.88	3.04
4	M20: without hair	20.587	3.176
5	1.5% hair	20.77	3.19
6	2% hair	21.885	3.275
7	M25:without hair	24.995	3.4996
8	1.5% hair	25.215	3.515
9	2% hair	26.105	3.5765

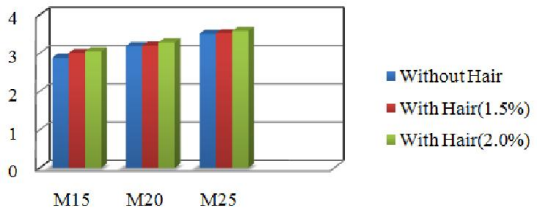

Fig. 2. Comparison on the basis of average flexural strength with varying percentages of hair fibre

After curing, place the specimen in the machine in such a manner that the load is applied to the uppermost surface along two lines spaced at a proper gauge length, at specified rate. Increase the load till the specimen fails. Note the appearances of the fractured faces of concrete.

Analysis of Results

When M15 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 4% in flexural strength and when M15 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 5% in flexural strength. When M20 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is not any appreciable increase in flexural strength and when M20 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 3% in flexural strength. When M25 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is not any appreciable increase in flexural strength and when M25 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 2% in flexural strength.

Conclusion

Human hair waste can be effectively managed to be utilized in fibre reinforced concrete constructions. According to the test performed it is observed that there is remarkable increment in properties of concrete according to the percentages of hairs by weight of cement in concrete. There was an overall increase of 1-12% in the compressive strength of concrete and up to 5% in the flexural strength of concrete test specimens by the addition of hair fibres in different quantities. It is well observed that the maximum increase is noticed in the addition of 2% hair fibre, by weight of concrete, in all the mixes. It is to be noted that maximum increase in the compressive strength is observed for lower concrete mixes, making the hair fibre reinforced concrete best suitable to use in the applications with those concrete mixes.

Crack formation and propagation are very much reduced showing that hair fibre reinforced concrete can have various applications in seismic resistant and crack resistant constructions, road pavement constructions etc.

Future scope of this study can be as follows:

- During our research work we also faced the problem of uniform distribution of hair in the concrete. So an efficient method of mixing of hair fibre to the concrete mix is to be found out.
- A wide study on partial replacement of cement using fine hair fibre is to be carried out.
- The study of admixtures and super plasticizer which could distribute the hairs without affecting the properties of concrete.
- The use of animal hairs in concrete.
- The research can be further extended to study the influence of hair fibre on other properties of composites such physical, thermal properties and appearances.

Applications

Crack Resistant Structures

According to Grimm, 1988, a crack may be defined as a "break, split, fracture, fissure, separation, cleavage or elongated narrow opening visible to the normal human eye and extending from the surface and into a masonry unit, mortar joint, interface between a masonry unit and adjacent mortar joint". The cracks are classified according to its damage level for load bearing masonry. In order to repair cracks up to a width of 5mm, either cement grouting can be used or steel wire meshes can be inserted into the cracks. But it is found that when fibre reinforced concrete is used, crack formation and propagation is very much reduced since fibres can form a strong bond with the concrete mix and can bridge the cracks to some extent. Examining the concrete specimens after the tests, it is found that only hair line cracks were formed after the compressive strength tests cracks in specimens with hair fibre

when compared with concrete specimens without hair fibre content. When fibres are added to concrete, it becomes homogeneous, isotropic and transforms it to a ductile material. These fibres will act as secondary reinforcement in concrete and reduces crack formation and propagation. the bridging effect by this fibre leads to the improvement in the tensile and flexural strength.

Seismic Resistant Structures

Safety against seismic forces is a combination of both structural stability and adoption of suitable construction techniques. It is well known that it is not the earthquake that kills people but the collapse of structures that causes the havoc. Light weight construction techniques have its application in this context. If the structure is light in weight at the same time stable in structural integrity, the problems caused by the collapse of buildings can be reduced. The possibility of hair fibre reinforced concrete can be discussed here. From the experimental results it is obvious that hair fibre reinforced concrete can be used for ordinary concreting works as such. For reinforced cement concrete, amount of steel reinforcement can be reduced by adopting required percentage of hair fibre reinforcement which makes the section light in weight. Reduction in crack formation under service loads gives better life time for the steel reinforcement as it will resist corrosion of steel through the cracks. Studies have been put forward the possibility of partial replacement of cement with fibres in fibre reinforced concrete. If it is feasible, the section will be economical without compromising the strength.

Road and Pavement Construction

Various studies have been conducted to find the effects of human hair additives in compressive strength of asphalt cement mixture as potential binder in road pavement and those prove that adding cement and human hair to asphalt mixture greatly increase the strength of the mixture thus making it a good material for the construction of road pavement. Adding of both cement and human hair to asphalt mixture improves the load bearing capacity of the mixture. Hence hair fibre reinforced concret has its application in construction of pavements also.

Water Proof Constructions

By adopting hair fibre reinforced concrete the formation of minute cracks can be limited which reduces the leakage problems, making it suitable for water proof constructions.

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APPENDIX

Selecting the hair fibres by measuring its length and diameter

Processing of hair fibre by washing with acetone

Preparation of specimens

Testing of samples

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